DESIGN 2002

THE ERASER PEN: A NEW INTERACTION PARADIGM FOR CURVE SKETCHING IN 3D

R. De Amicis, F. Bruno, A. Stork and M. L. Luchi

Keywords: 3D-interaction, free-form surface design, CAD, HCI

1. Introduction

One of the crucial parts during the process of creating and manipulating surfaces is to draw 3D curves. Effective techniques for specifying 3D curves using 2D input devices are been extensively developed, even if the creation of curves is usually limited to a plane but real objects require 3D curves. Nevertheless the main limits of these systems are related to the supplied modelling tools, which usually use the control points for creating and modifying the curves, thus requiring a certain mathematical knowledge and experience to know how to modify these points in order to obtain the desired surface. Conversely virtual reality offers stylists and designers the possibility to immediately sketch and model in 3D, combining the sketching and modelling stages of the design process. 3D input devices combined with form-descriptive gestures to sketch and deform models, three dimensionally and 3D output devices like virtual tables for direct immersive 3D visualization, have the potential to be much more effective because they to allow explore 3D space in a more intuitive and natural way [De Amicis 1999] [De Amicis 2001]. While in previous work [Stork 2000], we presented several different techniques to generate Free-Form surface, in virtual environments like coons patches from just one 3D outline stroke, skinned surfaces, Net-Surface, symmetric free-form surfaces by using a virtual palette as a mirror plane, etc. These approaches consist in redesigning the commonly used tools, obviously utilising a different paradigm that takes advantage of the capabilities offered by new 3D input devices.

The paper presents a direct manipulative technique called 3D-Eraser Pen. By means of this technique if the resulting polyline, curve or surface is not exactly what the designer wants, he/she can delete part of the sketch just going back and do it again and again until he/she reaches the final shape. In that way we have combined the creation and deletion process, rewriting the pencil and rubber metaphor in just one tool. The possibility to use a tool that allow the user to specify 3D curves in a very easy and natural way represents the major contribution to the paper. The combination of the semi-immersive environment with lightweight interaction devices and innovative interaction techniques facilitates intuitive free-form modeling at a Virtual Table.

2. Related Work

Although there is increasingly research work in the field of free-form surface modeling in virtual environments, [Butterworth 1992] [Dani 1997] [Dani 1999], there are only a few publications on curve sketching in 3D. Since surfaces can be derived from curves, curve input is the more fundamental task and has to be explored more deeply.

'3-Draw' is the pioneering work on creating curves directly in 3D by Sachs et al [Sachs 1991]. They used a pair of 6 degree-of-freedom tracking devices one attached to a palette and the other to a pen. The palette's orientation is used to define the reference coordinate system. The pen serves as a drawing and editing tool to create and change curves in 3D. Multiple curves could be connected to

wires. As a conventional monitor was used as output device without stereoscopy, the designer had to coordinate his movements with the scene displayed at the monitor. Curve creation and editing were two distinct tasks. Forsberg et al. [Forsberg 1997] address 3D curve creation at a table-like rear-projection system, but their focus lies more on creating annotations with 3D input devices and two-handed interaction techniques at the 'ActiveDesk' instead of dedicated interaction techniques for curve creation in free space.

An interface for sketching 3D curves with 2D input devices was presented by Cohen et al. [Cohen 1999]. Where curves are created first on an arbitrary plane by sketching a shadow, the 3D shape of a curve is altered. Curves and shadows can be 'overdrawn' to change their shape. As with 3-Draw the creation and manipulation of curves is split into two phases. The idea of overdrawing a curve first appeared by Baudel [Baudel 94] . He presents an approach to create 2D lines and change them just by partially redrawing them. The system then replaces the old by the new part. Baudel's approach is not modeless and he only addresses 2D curves, [Baudel 1994].

To the authors there is no known approach that tries to integrate the creation and editing phase, for 3D curves in free space, into one step. Herein we see the major contribution of our new interaction paradigm.

3. System Setup

In this section the hardware as well as the software in use is described. A Virtual Table, in our case the Barco Baron, a magnetic tracking system with three trackers, Polhemus Fastrak, and a pair of stereo-glasses constitute the hardware. The trackers determine the position and orientation of the user's head, the transparent pad and the pen. We use a flat transparent pen with three buttons and a wooden anatomically shaped handle, see Figure 1. The software toolset Studierstube/VT [Stork 2000], provides the perspectively correct stereoscopic rendering of the scene, as well as the possibility to use the pen and the pad as carrier of 3D widgets see Figure 2. Our 3D-modeling system is based on the OpenCascade modeling kernel, wich provides algorithms to interpolate or approximate point sets and curves by surfaces.
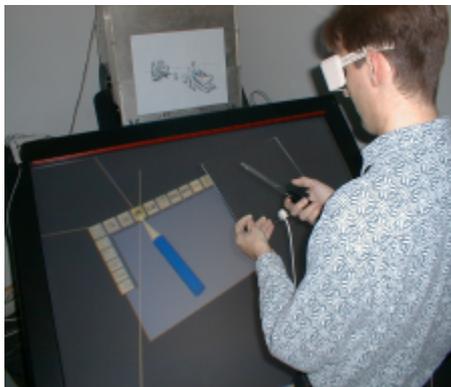
Figure 1. User at the VT with pad and pen
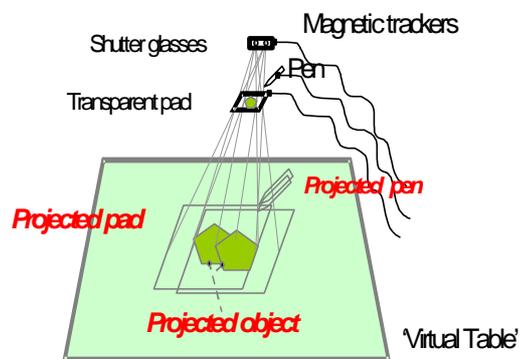
Figure 2. Hardware setup

4. The 3D Eraser Pen

During the styling process, usually, the designer tries many different sketches until the shape has the desired appearance. In traditional CAD system, and in general in 2D-environments for design, the user may use the rubber tool to correct the errors that occurred during the drawing process or the user may change the position of a control point to modify a curve directly. Also the 'undo' option is a commonly used way for correcting the errors or retry an operation. If we want to provide a natural tool for drawing shapes, by means of curves or surfaces, in a 3D-environment, we have to consider that the user must have the possibility to delete a shape whenever he or she likes. Instead of creating a simple rubber tool, like in the most 2D-graphic software, we propose a different approach and a new interaction technique to correct the forms during the drawing process.

Our idea is a very fast way to correct the shape during the drawing process. If the user realizes that an error was occurred when he or she was drawing, he or she can correct his or her mistake simply

coming back on path that he or she was following with the pen, see Figure 3.
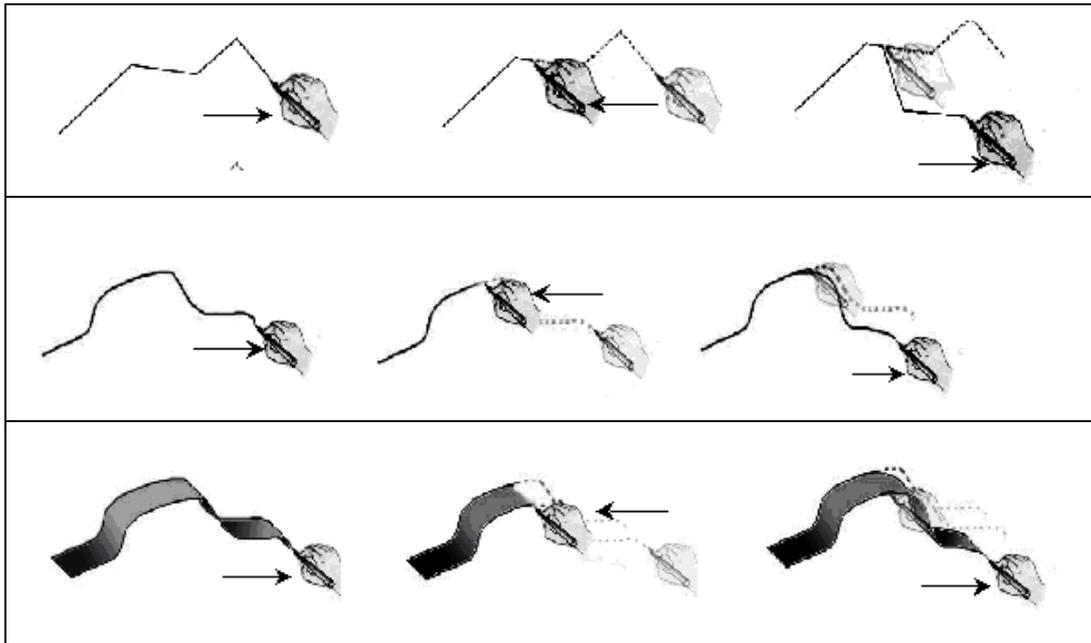
Figure 3. The 3D-Eraser Pen concept applied to polyline, curve and surface

In that way we have combined the creation and deletion process, rewriting the rubber and pencil metaphor in just one tool.

The correction is done in real time and if the pen inverts its direction for a second time the drawing process restarts. In this manner it is very simple to correct an error or coming back for following a different path. The advantage respectively the common use of a rubber tool is that the user can correct the curve instantaneously, and he/she may try and retry many times until the desired shape does not take the form as it is in his/her mind.
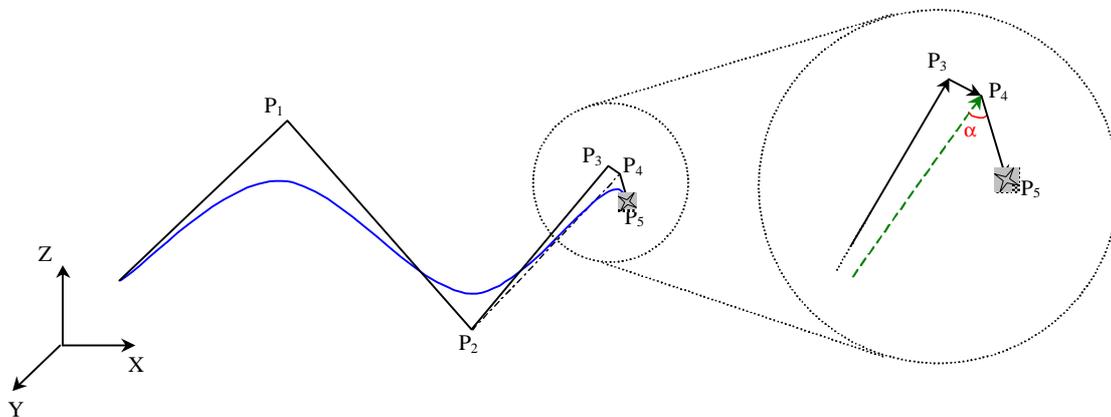
Figure 4. The 3D-Eraser Pen algorithm

4.1 Implementation

While the user moves the pen through the space, the system samples points to generate the 3D curve. The first and the current sampled point are interpolated while all the remaining points are approximated by the curve. With every pen movement the system calculates the angle between the current vector and the sum of the last vector and the previous one see Figure 4. When the angle is below a certain value, the system will interpret this situation like an inversion of the direction, as a consequence the last vector of the control polygon is deleted. The sum of the two vectors that have been drawn at least, represents a good average direction of them. Furthermore, the smaller the last

vector is, compared to the one that has been drawn previously, the more the sum vector will take into account the direction of the one that is previous to the last. On that account we can follow, with a good approximation, the shape of the curve, only examining the control polygon. The user does not have to go back to follow the last displacement vector done by the sensor, which is in some case too small to be followed, but he/she has only to follow the main direction of the curve. This approach immediately shows the big advantages offered by this technique. We have tested this algorithm in several situations either when curvature is small or when it is big and it works properly in every situation.

5. Application of the 3D-Eraser Pen

As proof of concept we implemented the 3D-Eraser Pen in the well known "extrude curve" tool. Extruding curves is a commonly used technique to define a surface. In traditional CAD-systems the user has to begin generating a line, polyline or curve which represents the profile of the final extruded surface. In a second time, he/she has to define a sweep path on which the profile has to be moved for generating the surface. After selecting the profile and the path, the extrude task can start and the user has to wait for the resulting surface generated by the system.

We implemented in our extrude tool an immediate visual feedback providing to the user a realistic idea about the final result of operation that he/she is performing. Furthermore, during the drawing process our system determines the curve accuracy by the pen movement speed, being the number of sample points related to the speed of the gesture.

The first step for the user is to draw the profile. When the pen is moved, the system draws a polyline and a curve at the same time. The user does not have to worry about the curve parameters like knots, control points, degree, he/she just moves the pen and a curve is being created. When the profile is made, the extrude process can start. The profile is attached to the pen and it follows the movement of the hand in translation and rotation. An immediate visual feedback is rendered giving to user the possibility to see the shape just like it will appear at the end of the process. Both, in drawing the profile curve and in extruding the phase the user can delete his shape simply coming back as described before, see Figure 4.
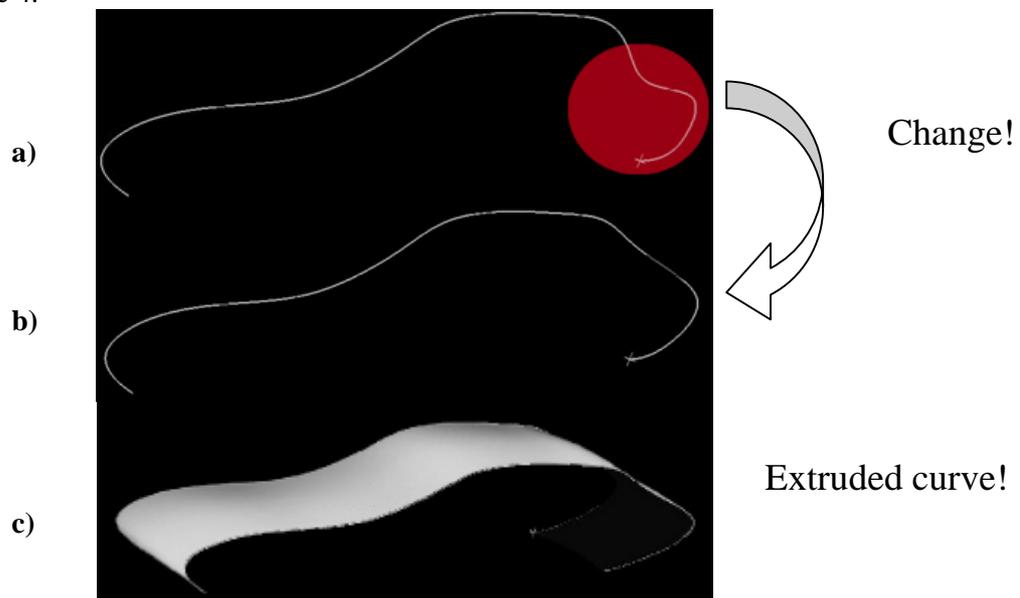
Figure 5. Generation of an extruded surface, a) first sketch, the red spot highlights the part that is redone, shown in b); c) surface by curve extrusion

The accuracy of the drawing process depends on the movement speed. If the user moves his/her hand slowly a more precise curve or surface was drawn, instead, if the movements are faster, like in a sketching process, the curve/surface is less accurate. This choice enables the system to reduce the number of control points and, consequently, the shape complexity when it is possible.

The union of these three features build an approach that resembles the hand gesture of the designer/stylist who doesn't trace a line in a single step but tries many times (with a variable speed

depending on the desired accuracy) until the sketch takes the desired appearance.
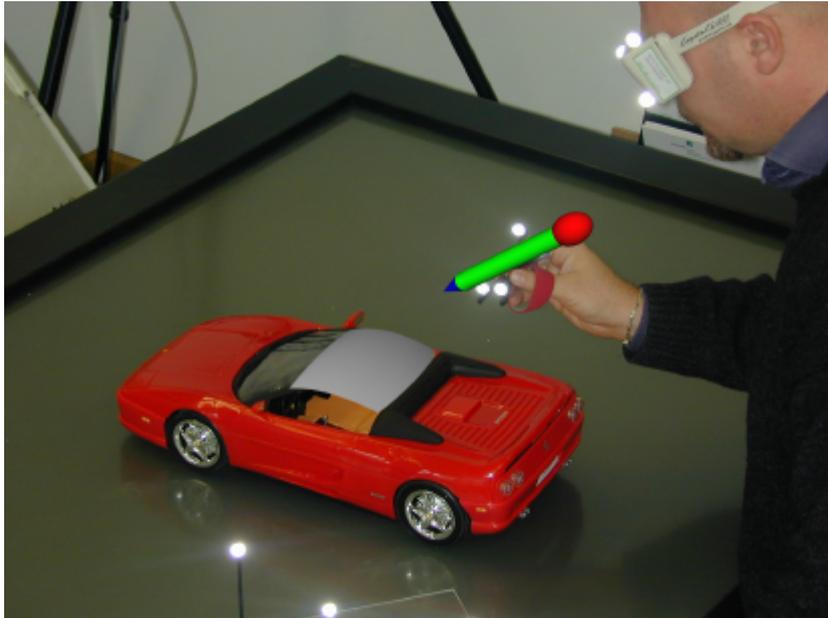
Figure 6. An example of the Erase Pen in an Augmented Reality Set-Up

6. Conclusions and Further Work

In this paper we presented a new interaction paradigm: the 3D-Eraser pen. The 3D-Eraser pen combines the formerly distinct tasks of creation and editing into one step. We have applied the idea of the eraser pen for 3D-curve and surface creation. The user can draw a curve in a 'forward' movement. By moving 'backwards' he/she erases what he/she has just drawn, changing the direction again enables him/her to continue to draw. Switching the modes is automatically performed by the system.

The 3D-Eraser pen resembles the pen and paper metaphor but is goes beyond the capabilities of physical pen and paper, since it is not necessaryto change from pen to eraser and vice versa. Compared to known approaches for curve input, it seamlessly integrates the phase of drawing and 'overdrawing'.

In the future we intend to use the 3D-Eraser pen also for 2D-input, expand its application to other free-form sketching techniques for coons patches, net-surfaces, etc.

We also plan to investigate whether the motor-perceptual memory of human beings is sufficient to remember the 'old' movement and resulting shape to allow to draw the new one in a way that better fits to the intended shape.

References

Baudel, T.,” A Mark-Based Interaction Paradigm for Free-Hand Drawing”, UIST ACM, November, 2-4,1994

Butterworth, J., Davidson, A., Hench, S., Olano, T.M. ,”3DM: A Three Dimensional Modeler Using a Head-Mounted Display”, Communications of the ACM, 55-62, June 1992,135,138

Cohen, J.M., Markosian, L., Zeleznik, R.C, Hughes, J.F., Barzel, R.,” An Interface for Sketching 3D Curves” 1999 Symposium on Interactive 3D Graphics, pp. 17-21, ACM 1999

De Amicis, R., Fiorentino, M., Stork, A.,“Parametric Interaction for CAD application in Virtual Reality Environment”; Proceedings of 12th International ADM Conference on “Design Tools and Methods in Industrial Engineering”; Sep. 5-7, 2001 Rimini ,Italy

De Amicis, R.,Brunetti,G.,"Virtual Engineering and Using Virtual Reality for Engineering", Proceedings of 11th International ADM Conference on "Design Tools and Methods in Industrial Engineering"; , pp. 153-161, Dec. 8-12 1999 Palermo,Italy

Dani, T.H.,Gadh, R.,"COVIRDS: A Conceptual Virtual Design System. Journal of Computer Aided Design, Vol. 29(8):555-563, 1997

Dani,T.H.,Wang, L.,Gadh, R.,"Free-Form Surface Design in a Virtual Environment", Proceedings. of ASME '99 Design Engineering Technical Conferences, ASME 1999

Forsberg, A.,LaViola, J.,Markosian,L.,Zeleznik,R.,"Seamless Interaction in Virtual Reality", Journal of IEEE Computer Graphics & Applications, 17(6):6-9, 1997

Sachs, E., Roberts, A. ,Stoops,D.,"3-Draw: A Tool for Designing 3D Shapes", Journal of IEEE Computer Graphics & Applications, 18-26,1991

Stork, A., De Amicis, R.," Skectching Freee-Forms in Semi-Immersive Virtual Enviroments",Proceedings of 2000 ASME Design Engineering Technical Conferences, and Computers and Information in Engineering Conference, Baltimore, Maryland, September 10-13,2000

Dr. Ing. Raffaele de Amicis
GRIS Dep. of Computer Science, Technische Universität Darmstadt
Fraunhoferstraße 5, Darmstadt, Germany
Tel.+49 6151 155 478, Telefax ++ 49 6151 155 299
Email: Raffaele.De.Amicis@gris.informatik.tu-darmstadt.de